MULTI-LEVEL COMPUTATIONAL MODEL FOR FIBER REINFORCED COMPOSITES WITH INTERFACIAL DEBONDING

S. Ghosh, P. Raghavan, S. Li and **B. Jie**

Department of Mechanical Engineering
The Ohio State University
Columbus, Ohio 43201
ghosh.5@osu.edu

A multi-scale methodology is developed to predict evolution of variables at the structural and microstructural scales, as well as to tract the incidence and propagation of microstructual interfacial debonding in fiber reinforced composite materials. The model introduces three levels in the computational domain that includes macro, macro-micro and microscopic analysis. It differentiates between non-critical and critical regions and ranges from macroscopic computations using continuum constitutive relations to zooming in at 'hotspots' for pure microscopic simulation. A coupled analysis method is used to couple all three computational domains.

The microstructual debonding analysis is conducted with the Voronoi Cell Finite Element Model (VCFEM) in conjunction with cohesive zone models. Cohesive zone interfacial models are powerful to depict failure as a separation process across an extended crack tip, where the interface is described as a number of nonlinear springs along the interfacial normal and tangential directions. Tractions across the interface reach a maximum, subsequently decrease and eventually vanish with the increment of the interfacial displacement jump.

A conventional displacement based FEM method executes the macroscopic analysis. A Continuum Damage Model is developed for macroscopic analysis, wherein damage is viewed as a macroscopic state variable (scalar, second order or fourth order tensor) which results in the reduction of stiffness. Most popular damage models represent damage as a scalar resulting in an isotropic damage or as a second-order tensor capable of exhibiting at most orthotropic stiffness degradation. Due to non-symmetric behavior of the cohesive zone model in tension and compression, damaged stiffness can become anisotropic especially in combined tension/shear loading conditions. To account for the evolution of damaged induced anisotropy, the fourth order stiffness tensor is considered as an internal variable. All constants are obtained by homogenization of the RVE.

In regions of severe macroscopic gradients, the results obtained using continuum models are not valid. With the multi-scale methodology proposed, a hierarchy of computational domains is created with varying resolution. The critical regions are modeled with complete microscopic analysis, whereas continuum models are used for non-critical regions. A numerical example with be used to demonstrate the effectiveness of this multi-level model.

References

[1] Ghosh, S., Lee, K., Raghavan, P., "A multi-level computational model for multi-scale damage analysis in composite and porous materials" *International Journal for Solids and Structures*, v. 38, p. 2335-2385, 2000.